Abstract for submittal to 2005 CALCON Technical Conference on Characterization and Radiometric Calibration for Remote Sensing, August 22–25, 2005, Logan, Utah, USA

Stennis Space Center Verification & Validation Capabilities

Mary Pagnutti, Robert E. Ryan, Kara Holekamp, Duane O'Neal, Kelly Knowlton, Kenton Ross, and Slawomir Blonski

Science Systems and Applications, Inc.

Scientists within NASA's Applied Sciences Directorate have developed a well-characterized remote sensing Verification & Validation (V&V) site at the John C. Stennis Space Center (SSC). This site enables the in-flight characterization of satellite and airborne high spatial and moderate resolution remote sensing systems and their products. The smaller scale of the newer high resolution remote sensing systems allows scientists to characterize geometric, spatial, and radiometric data properties using a single V&V site. The targets and techniques used to characterize data from these newer systems can differ significantly from the techniques used to characterize data from the earlier, coarser spatial resolution systems. Scientists are also using the SSC V&V site to characterize thermal infrared systems and active lidar systems. SSC employs geodetic targets, edge targets, radiometric tarps, atmospheric monitoring equipment, and thermal calibration ponds to characterize remote sensing data products. The SSC Instrument Validation Lab is a key component of the V&V capability and is used to calibrate field instrumentation and to provide National Institute of Standards and Technology traceability. This poster presents a description of the SSC characterization capabilities and examples of calibration data.

This work was directed by the NASA Applied Sciences Directorate at the John C. Stennis Space Center, Mississippi. Participation in this work by Science Systems and Applications, Inc., was supported under NASA Task Order NNS04AB54T.

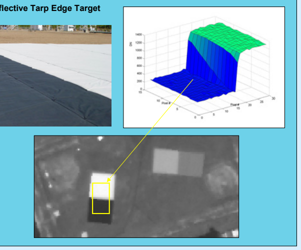
Stennis Space Center
Verification and Validation Capabilities

Mary Pagnutti, Robert E. Ryan, Kara Holekamp, Duane O'Neal, Kelly Knowlton, Kenton Ross, and Slawomir Blonski
Science Systems and Applications, Inc.
John C. Stennis Space Center, MS 39529

Spatial Response

Edge Response of Tarps

Reflective Tarp Edge Target

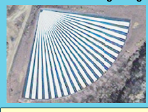


Painted Concrete Edge Target

Purpose: Measure spatial response of 1-meter GSD class systems
Reflectance: ~50% and ~4% reflective painted rectangles
Dimensions: 4 rectangles, 10 m x 20 m each
Total Dimensions: 20 m x 40 m
Orientation: North-South and East-West orientation

Painted Concrete Tri-bar Target Array

Painted Concrete Radial Edge Target



- 130 m radial target > 90° arc angle
- ~4 m thick tapered to < 10 cm

Reflectance Radiometry

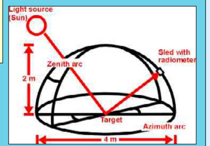
ASD Measuring Tarps

Analytical Spectral Devices

Purpose: Analytical Spectral Devices (ASDs) used to calibrate accurately target reflectance values used to validate imager radiance values
Spectral Range: 350 - 2500 nm
Sensors: One 512-element photodiode array and two thermoelectrically cooled, extended-range InGaAs photodiodes
Sampling Interval: 1.4 nm from 350 - 1000 nm; 2 nm from 1000 - 2500 nm
Spectral Resolution: 3 nm @ 700 nm; 10 nm @ 1500 nm; 10 nm @ 2100 nm
Number of Channels: 512 channels
Wavelength Accuracy: ±1 nm

Goniometer

Purpose: Measure BRDF effects of target surface
Spectral Radiometer: GER
Zenith Range: 180° sampled every 15°
Azimuthal Range: 180° sampled every 30°

NIST characterized Spectralon© Panels

Reflective Tarps

Purpose: Tarp panels form two 20-meter edges to measure the edge response of panchromatic and multispectral imaging systems with ground sampling distances of 1 meter or less

Tarps' highly uniform spectral reflectance can be utilized in the characterization of multispectral and hyperspectral sensors

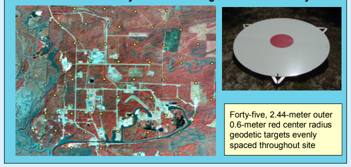
- Tarp Panel 1 - 3.5% Reflectance
- Tarp Panel 2 - 22% Reflectance
- Tarp Panel 3 - 34% Reflectance
- Tarp Panel 4 - 52% Reflectance

Positional Accuracy

QuickBird Observed Geolocational Accuracy

QuickBird Product	Acquisition Date	Empirical CE_{90} (m)	Empirical CE_{95} (m)	Elevation Angle (deg)
Panchromatic Standard	8/23/2003	12.67	12.76	76.8
	9/15/2003	17.40	17.62	83.3
	10/21/2003	13.63	13.72	81.3
	1/10/2004	16.27	16.39	89.2
Panchromatic Orthorectified	8/23/2003	7.93	8.11	76.8
Multispectral Standard	8/23/2003	12.78	12.93	76.8
	9/15/2003	17.34	17.66	83.3
	10/21/2003	13.76	13.77	81.3
Multispectral Orthorectified	8/23/2003	7.50	8.43	76.8

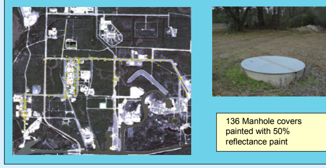
45 GPS-Surveyed Geodetic Targets < 3 cm Accuracy



Forty-five, 2.44-meter outer 0.6-meter red center radius geodetic targets evenly spaced throughout site

17 A-Order monuments On Site

136 Manhole Covers On Site—9 m to 2.44 m

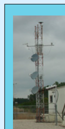


136 Manhole covers painted with 50% reflectance paint

Trimble 5700 GPS

- Centimeter-level accuracy
- Sub-cm accuracies for static survey
- 24-channel receiver

NGS/NOAA-NDBC Operated CORS Site



Continuously Operating Reference Station provides carrier phase and code range measurements for added ease of post-processing GPS survey data

Trimble Pathfinder GPS

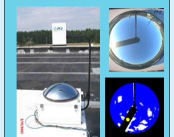
Purpose: Field portable real-time GPS survey
Accuracy: 10 m to submeter

Stationary Atmospheric Monitoring

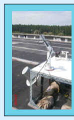
Atmospheric Monitoring Station

- Live Web publishing
- Entirely automated

Total Sky Imager

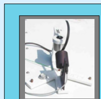


Cimel Sun Photometer



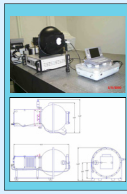
Channels: 440, 670, 870, 936, and 1020 nm
FWHM: 10 nm
FOV: 1.2°
Part of AERONET network

Multi-filter Rotating Shadow-band Radiometer



Laboratory Calibration

NIST-Certified Integrating Spheres

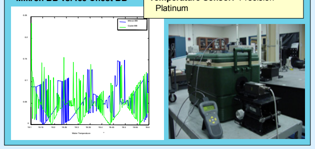


Purpose: Calibration and characterization of spectral radiometers
Controls: Microprocessor-controlled integrating sphere calibration standard
Illumination: 150-W tungsten-halogen, reflectorized lamp with a motorized, computer-controlled, variable aperture
Temperature Range: 2000 to 3000K
Spectral Range: Calibrated from 300 to 2500 nm

Mikron Water Bath Blackbodies

Purpose: Calibration of radiometers
Emitter Area: 12" x 12"
Temperature Range: 0 °C to 148.9 °C
Temperature Resolution: 0.01 °C ≤ 99.99 °C; 0.1 °C ≥ 100 °C
Stability: ±.04 °C for 8-hour period
Temperature Sensor: Precision Platinum

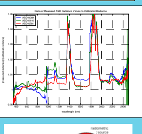
Mikron BB vs. Ice Chest BB



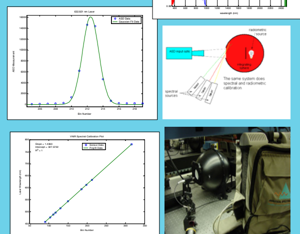
Calibration & Characterization of ASD FieldSpec Spectroradiometers

Purpose: Perform spectral and radiometric calibration of ASD FieldSpec Pro spectroradiometers

Radiometric Calibration: NIST-calibrated integrating sphere serves as source with known spectral radiance
- Calculate coefficients for conversion of measured DN values to radiance
- Perform periodic checks of ASD radiance calibration using known radiance source
- Check linearity of ASD response by varying integrating sphere radiance level



Spectral Calibration:
- VNIR - laser illumination of integrating sphere produces monochromatic Lambertian source
- SWIR - use gas discharge lamps to illuminate integrating sphere
- Fit Gaussian curve to each spectral peak to estimate bin number corresponding to wavelength at center of peak
- Perform linear regression to assign wavelengths to all spectral bins



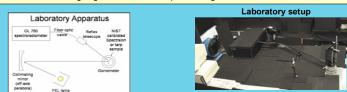
ESPEC Environmental Chamber

Purpose: Simulation of field conditions to validate instrument performance under non-laboratory conditions
Temperature Range: -75 °C to 150 °C
Relative Humidity Range: 10% to 90%
Interior Dimensions: 32 ft³

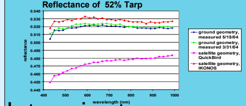
Bidirectional Reflectance

Purpose: Evaluate target bidirectional reflectance to account for the differences between ground measurement viewing angles and satellite acquisition angles

Laboratory setup



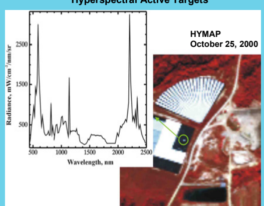
Reflectance of 52% Tarp



Test results indicate that bidirectional reflectance effects can change the effective reflectance by as much as 10%

Hyperspectral Radiometry

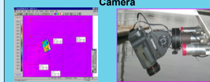
Hyperspectral Active Targets



Purpose: Vicariously evaluate wavelength calibrations of airborne hyperspectral sensors
Design: 1500 W metal halide lamps

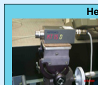
Thermal Radiometry

FLIR Systems SC2000: Thermal Camera



Purpose: Image float's influence on waterbody
Range: Thermal (8-12 μm)
Accuracy: 14-bit digitization with 0.1 °C NED, 240 x 320 pixel array
IFOV: Uncooled, 1.3 milliradian

Heimann Radiometer

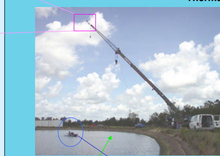


Spectral Response: 8-14 μm
Accuracy: ±0.5 °C
Target Spot Size (@ 1 m): 10 cm
Response Time: 0.05-10.0 seconds

FTIR Spectropolarimeter

Purpose: Measure hyperspectral thermal data in two polarization
Resolution: ~0.5 (cm^-1) in two polarizations
Range: 5000-600 (cm^-1) for KBr
Detector: LN2 cooled MCT

Thermal Float on Stennis Pond

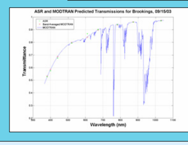


- Float employs 2 Heimann radiometers to measure skin surface temperature
- Additional Heimann measures cold sky temperature
- Two honeycomb black bodies calibrate radiometers during field exercises
- Thermocouple probe measures bulk water temperature

Portable Atmospheric Monitoring

Automated Solar Radiometer

Purpose: Measure direct solar irradiance
Spectral Channels: Nine channels – one total solar and eight 10 nm bandwidth center wavelengths at 382, 400, 440, 521, 610, 671, 781, 870, 940, and 1030 nm

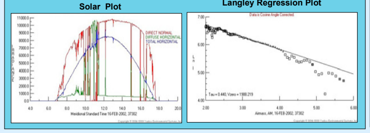


Multi-filter Rotating Shadow-band Radiometer

Purpose: Measure diffuse/ direct/horizontal solar irradiance
Spectral Channels: Seven channels – one total solar and six 10 nm bandwidth center wavelengths at 415, 500, 615, 673, 870, and 940 nm
Cosine response: <5% for 0-80 degree zenith angle; <1% with correction

Solar Plot

Langley Regression Plot



Radiosonde Balloon

Full Sky Imager

Portable Meteorology Station

Purpose: Record atmospheric measurements during field collects
Atmospheric Measurements: Temperature, humidity, pressure, and wind speed/direction sensors
Solar measurements: Pyrenometer, Pyroheliometer

This work was directed by the NASA Applied Sciences Directorate at the John C. Stennis Space Center, Mississippi.
Participation in this work by Science Systems and Applications, Inc., was supported under NASA Task Order NNS04AB54T.

Contact Information – phone: 228-688-2135; e-mail: Mary.Pagnutti@ssc.nasa.gov
2005 CALCON Technical Conference on Characterization and Radiometric Calibration for Remote Sensing, August 22–25, 2005, Logan, Utah, USA

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
22-08-2005

2. REPORT TYPE
Final - Abstract and Poster

3. DATES COVERED *(From - To)*
1998 - 2005

4. TITLE AND SUBTITLE
Stennis Space Center Verification & Validation Capabilities

5a. CONTRACT NUMBER
NASA Task Order NNS04AB54T

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Pagnutti, Mary
Ryan, Robert E.
Holekamp, Kara
O'Neal, Duane
Knowlton, Kelly
Ross, Kenton
Blonski, Slawomir

5d. PROJECT NUMBER
SWR C15C-JC15-00

5e. TASK NUMBER

5f. WORK UNIT NUMBER
MA00

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Applied Sciences Directorate, Science Systems and Applications, Inc., Bldg. 1105, John C. Stennis Space Center, MS 39529

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Applied Sciences Directorate, National Aeronautics and Space Administration, Code MA00, Bldg. 1100, John C. Stennis Space Center, MS 39529

10. SPONSORING/MONITOR'S ACRONYM(S)
NASA ASD

11. SPONSORING/MONITORING REPORT NUMBER
SSTI-2220-0044 (Modified)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Publicly available STI per NASA Form 1676

13. SUPPLEMENTARY NOTES
Poster displayed at 2005 CALCON Technical Conference on Characterization and Radiometric Calibration for Remote Sensing, August 22-25, 2005, Logan, Utah, USA. NOTE: The abstract is a modification of the abstract from a paper previously approved for release as PNS SE-2002-10-00070-SSC. The poster is a modification of a poster previously approved for release as PNS SE-2002-03-00029-SSC.

14. ABSTRACT
Scientists within NASA's Applied Sciences Directorate have developed a well-characterized remote sensing Verification & Validation (V&V) site at the John C. Stennis Space Center (SSC). This site enables the in-flight characterization of satellite and airborne high spatial and moderate resolution remote sensing systems and their products. The smaller scale of the newer high resolution remote sensing systems allows scientists to characterize geometric, spatial, and radiometric data properties using a single V&V site. The targets and techniques used to characterize data from these newer systems can differ significantly from the techniques used to characterize data from the earlier, coarser spatial resolution systems. Scientists are also using the SSC V&V site to characterize thermal infrared systems and active lidar systems. SSC employs geodetic targets, edge targets, radiometric tarps, atmospheric monitoring equipment, and thermal calibration ponds to characterize remote sensing data products. The SSC Instrument Validation Lab is a key component of the V&V capability and is used to calibrate field instrumentation and to provide National Institute of Standards and Technology traceability.

15. SUBJECT TERMS
verification & validation, V&V, calibration, characterization, radiometry, spatial response, positional accuracy, remote sensing

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19b. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	2	Thomas M. Stanley / (228) 688-7779

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18